- SCOPE: The purpose of this article is to introduce you to photoresist coatings, their purpose, composition, application methods and development.

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INTRODUCTION TO PHOTORESIST COATINGS

The role of the photoresist coating

Its main purpose is to protect areas of a substrate during subsequent lithographic processing steps, such as wet or dry chemical etching.

Applied as a liquid, the photoresist changes chemically when exposed to light (most commonly UV). By controlling (through a mask, for example) which areas of the photoresist are exposed to the light and which are not, patterns/areas of exposed and unexposed resist can be created.

The photoresist will be either positive or negative. Relative to the non-transparent shapes on a mask:

- The use of **positive** photoresist (the most common) results in areas of the photoresist corresponding to transparent shapes on the mask becoming more soluble in a developer (see later). In essence, a positive resist produces a positive image of the mask's transparent shapes. Think: "Positive – Mask shapes will be etched".
- A **negative** photoresist results in areas of the photoresist corresponding to non-transparent shapes on the mask becoming more soluble in a developer. Think: "Negative – Mask shapes will not be etched."

Following exposure and development, the substrate will have protected and unprotected areas.

The resist can be applied using a number of methods (see later), but the goal is usually to obtain a layer of a uniform thickness of between 1 and 10µm in most cases, although some applications can require a thickness of more than 100µm.

Photoresist is mainly used as a processing step. It is nearly always removed and seldom part of the finished product. During the fabrication of a semiconductor or a MEMs, resist will be applied and removed several times; each time a layer is fabricated.

One last key aspect to touch on here is cost. Photoresist is a relatively expensive consumable, so the amount of waste needs to be considered when deciding on an application method. It also has a shelf life.

Resist composition

As a minimum, the resist will include a resin, a photoactive substance (known as the inhibitor or sensitiser) and a solvent (either water based or an organic solvent). It may also contain a dye (to aid visual inspection) and anti-oxidising agents.

Storage and handling considerations

As a photoresist changes chemically under light, this has to be considered when storing and handling. It is typically supplied in non-transparent bottles, the labels of which will recommend a storage temperature (or rather a temperature range) and give an expiry date.

Out of the bottle, the resist should only be handled under yellow light – up to the point at which it will be exposed to light for activation purposes, of course.

Preparation

Before a photoresist can be applied, a substrate must be:

- Clean. For this, an inert gas, typically nitrogen or argon, is blown across the surface.
- Dehydrated. It is important that any moisture that may have been absorbed by the substrate is removed. Baking in a convection oven at 400°C (or a furnace tube at 800°C) is a common way of assuring dehydration.
- Primed. Though not technically a 'must', priming is highly recommended. It keeps the wafer dehydrated and improves resist adhesion. Most primers are applied as a vapour and a common one used in volume production scenarios is hexamethyldisilazane (HMDS).

Application methods

Here are the most common ones:

- **Spin-coating.** This is a four-step process. 1/ A small volume (a few ml) of resist is placed in the approximate centre of a wafer. 2/ the wafer is spun (accelerated up to a few 1,000rpm) until the resist (drawn out by centrifugal force) has spread evenly and is rotating at the same speed as the wafer [this step is often termed 'spin up']. Note: step 1 then step 2 is 'static spin-coating'. However, the wafer can also be spun first (step 2 then 1) for 'dynamic spin coating'). 3/ Further spinning [a step called 'spin off'] sees excess resist flung off the wafer. 4/ The wafer is spun until the desired thickness is achieved (by which time most of the solvent will have evaporated). All four steps typically take no more than a minute. Spin coating is ideal for flat-surface substrates of up 450mm in size. *Typical thickness range: 0.5 to 100µm.*
- **Spray**. This method is ideal for large substrates, or which have already been etched to produce structures (for a MEMS, for example). Resist can be applied to the tops and sidewalls of structures, though achieving a

uniform thickness can be challenging but is not impossible. The ‘spray’ is effectively atomised resist, produced using a pressurised nitrogen gas and nozzle or ultrasonic atomisation. *Typical thickness range: 1 to 50µm.*

- **Dip coating**. As the name suggests, the substrate is dipped into the resist. The method is useful for substrates of a size or shape that make them unsuitable for spin-coating or to minimise waste on a per substrate basis. For example, during spin-coating only a small percentage of the resist that is applied remains on the substrate after it has been spun. In this respect, spin-coating is quite wasteful. However, dip coating does of course require a full tank of resist before the first substrate can be dipped. *Typical thickness range: 1 and 20µm.*
- **Inkjet printing**. This works in a similar fashion to spray-coating, producing droplets of photoresist. Unlike spray-coating however, these drops are produced in a stream rather than a mist. This stream of droplets can then be precisely controlled and patterned onto the substrate. *Typical thickness: more than 10µm.*
- **Slot die**. It is a scalable manufacturing technique used in a range of industrial processes to produce uniform films and coatings. A print-head continuously dispenses the photoresist onto the surface of a moving substrate, producing a uniform film of photoresist. As the solvent within the wet photoresist evaporates, the photoresist film dries leaving a uniform thin film that can then be processed further. *Typical thickness: more than 0.5µm.*

Where thicknesses and ranges are expressed, the figures are ‘typical’. Plus, we are talking in terms of a single process step.

For all listed methods, the resist’s composition, viscosity and dilution will affect the thickness. Spin coating is also affected by spin speed, spray coating by drop size (and time spraying), dip-coating by the rate at which the substrate is drawn from the tank and slot die coating by the speed at which the substrate is moving.

Each process has its pros and cons. Selection considerations will include target volumes, waste and any challenges associated with the complexity of the patterns to be achieved. For further information on all the above, refer to our Knowledge Base article Resist Coating Methods.

Following the application of the photoresist, the substrate is typically soft-baked, at circa 100°C, to remove all solvent.

Light sensitivity

The energy absorption of any given photoresist depends on its chemical composition and the wavelength of the applied light. The spectral range of most photoresists goes from near-visible short wavelength to ultraviolet (UV).

For example, the products of OEM Allresist are (according to published data) sensitive in the broad band UV range (300 – 450 nm) and thus to the typical emission lines of mercury at 365 nm (i-line), 405 nm (h-line), and 436 nm (g-line), with maximum sensitivity in the g-line- and the h-line range.

Allresist also lists many of the parameters that govern the sensitivity and performance of its products. We paraphrase some below as they will typically be true for all resists, irrespective of manufacturer. Resist chemistry aside, the parameters are:

- Applied thickness
- Bake conditions (including temperature, time and equipment type)
- Exposure device
- Exposure wavelength
- The developer used (type, concentration and time in contact with the photoresist)
- Time after bake and after exposure
- Rehydration time after the bake.

Development

Although the focus of this article is on photoresist, we will conclude with a few words on development. This step follows exposure and soft bake. It removes the exposed or unexposed resist (depending on whether it is positive or negative, respectively) in readiness for etching. The substrate is generally either immersed into or sprayed with a developer fluid.

The development process is relatively brief (typically less than one minute) as the ‘protective’ resist has, as mentioned, been made less soluble. It is not *impervious* to the developer. To ensure pattern integrity, it is important that the substrate is not in contact with the developer for longer than necessary and that it is rinsed and dried as soon as possible.

The datasheet of any given photoresist will typically recommend a number of suitable developers and indicate how they should be used (in terms of dilution, contact time, temperature etc.).